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Proximate Composition, Mineral Contents and the effects of Sodium Sulphate Salts on Emulsion Capacity and Stability of Mushroom Species obtained from Nigeria

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Abstract

The proximate composition, mineral contents and the effects of sodium sulphate salts on emulsion capacity (EC) and stability (ES) of mushroom species M_1 – *Lentinus subnudus* Berk, M_2 – *Chlorophyllum molybditis*, M_3 – *Volvariella esculenta*, M_4 – *Coprinus tramentarius*, M_5 – *Pleurotus ostreatus* Jacq, M_6 – *Termitomyces microcarpus*, and M_7 – *Pleurotus pulmonarius* obtained from Nigeria were investigated using standard methods for analyses. The mean of some of the results is: Crude protein: 9.1±0.15 -13.80±0.15%, Crude fibre: 4.15±0.02 – 7.08±0.59%, Na: 177±2.56 – 910±2.56 mg/100 g, P: 480±2.31 – 884±2.43 mg/100 g and Cu: 0.23±0.23 – 0.23±0.23 mg/100 g. In the study, EC and ES were affected by different salt concentrations. In water, the EC results varied from 76.26±20.17 (M_2) to 85.70 ± 20.17% (M_7) and significantly differed from one another at $p > 0.05$. The EC of samples in different salt concentrations ranged as follows: 64.48 -86.18, 68.18 - 75.10, 67.18 - 74.51, and 61.48 -75.01% at 2, 4, 6, 8% of the salt concentrations respectively. Salt applications gave lowest ES and EC. These results indicated the interaction between the oil, salt solutions, the mushroom samples, and the blender used to form the emulsions. In stable ES, the interfacial area did not change with time. Consequently, such emulsions have a constant turbidity. In this report, it was observed that coalescence and oiling-off caused an irreversible reduction in the interfacial area. In conclusion, the good emulsifying capacity and stability showed the usefulness of the samples in the food industries and formulations.

Keywords: Mushroom, *Coprinusa tramentarius*, Protein, Sodium Sulphate, Food industry

Introduction

Edible mushrooms are known to be an excellent source of nutrients and bioactive compounds [1]. They are healthy diets due to their excellent nutritional profile. Mushroom species have high protein, essential amino acids, low fat, large amount of carbohydrates, and fibre, vitamins (B1, B2, B12, C and D) and mineral elements (Ca,K, Mg, Na, P, Cu, Fe, Mn and Se) [2].Crude protein is high in edible mushrooms and range between 15.2 g/100 g dried weight in *Lentinus edodes* to 80.93 g/100 g dried weight in *Agaricus bisporus* [2]. Generally, the biological quality of mushroom proteins is high [3]. Mushroom species are considered rich in glutamic acid, aspartic acid, and arginine, but their proteins are deficient in methionine and cysteine. The mushroom has been found to contain two amino acids: γ-amino butyric acid (GABA) and ornithine, which have shown important physiological activities as a neurotransmitter in the central nervous system (CNS) and precursor in the synthesis of arginine, respectively [4].

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According to Chandra et al. [5], functional properties are the physicochemical properties that show the complex interaction between the composition, structure, molecular conformation and physicochemical properties of food components together with the nature of the environment in which these are associated and measured [6]. Functional characteristics are needed to evaluate and assist to predict how new proteins, carbohydrates, fat, and fiber may act in specific systems as well as demonstrate whether or not such protein can be used to stimulate or replace conventional protein [6]. The functional property of food is characterized by the structure, quality, nutritional value and /or acceptability of a food product. Example of functional properties may include solubility, absorption, water retention, frothing ability, elasticity and absorptive capacity for fat and foreign particulars [7]. Other functional properties include emulsification, hydration (water-binding), viscosity, foaming, solubility, gelation, cohesion, and adhesion. Emulsion Capacity (EC) is the maximum quantity of oil that is emulsified under specific conditions by a standard amount of protein while Emulsion Stability (ES) is a measure of the quantity of oil and /or cream separating from an emulsion during a certain period of time at a stated temperature and gravitational field or The time required for a specific degree of breakdown to occur [8]. Emulsion formation strictly depends on the ability of proteins.

Sathe and Salunkhe [9], have shown that the presence of salt may increase the total water of the protein system at particular water activity content. The effects of salt are markedly dependent on the nature of the ion (anion and cation) components [10]. The effects of the ions are influenced by the intensity of their surface charge [11].

Mushroom growing is a cool and high profit yielding business in Africa and the Asian countries, but during glut period, storage has been the major problem which eventually results in waste [12]. To arrest this issue of wastage, it is not out of contest if functional property using salt application is employed. Several efforts have been made by researchers worldwide on food, functional properties using different salts (Table 1), not much was dealt on mushrooms and the use of sodium sulphate in food property (emulsion capacity and stability). In this premise, the objective of this study involves the collection of data on the emulsion capacity and stability of seven mushroom species using varying concentrations of sodium sulphate. This will provide the useful information to food industries and others to make cheap, natural and acceptable functional foods.

MATERIALS AND METHODS

Source of Materials

Sample Pretreatment

The mushrooms Figure-1, M_1 – *Lentinus subnudus* Berk, M_2 – *Chlorophyllum molybditis*, M_3 – *Volvariella esculenta*, M_4 – *Coprinus tramentarius*, M_5 – *Pleurotus ostreatus* Jacq, M_6 – *Termitomyces microcarpus*, and M_7 – *Pleurotus pulmonarius* were collected from the Federal College of Agriculture campus, Akure, Ondo State, southwest part of Nigeria. The samples were prepared by removing the bad ones, washed with distilled water, oven dried at 65^{o}C for 72 hours and were then pounded into the powdered form using porcelain pestle and mortar. The milled samples were then sieved with a 2mm mesh sized sieve and stored in waterproof polyethylene bags at room temperature for further analysis.

Determination of the proximate and mineral compositions

The methods adopted by Association of Oil Analytical Chemist (AOAC International) [13] were used in the determination of the proximate compositions. The calorific values in kilojoules were calculated by multiplying the protein, crude fat, and carbohydrate by Atwater factor of 37, 17 and 17 [14].

Determination of Emulsion Stability (ES)

The emulsion was prepared using Beuchat's procedure [15]. 1g of the sample was blended in a Kenwood blender with 50 mL cm^3 of distilled water for 30 Sec at maximum speed. Executive chef vegetable oil was added in 5 mL cm^3 portions with continuous blending. A drop inconsistency was considered the point at which to discontinue oil addition. The emulsion prepared was then allowed to stand in a graduated cylinder and the volume of water separated at intervals between 1 and 24h was noted in each case. For salts determinations, different salt concentrations were used in place of distilled water. Determinations were done in triplicates.

$$\text{Calculation (\%)} = \frac{\text{Height of the emulsified layer}}{\text{Height of total content in the tube}} \times 100$$

Determination of Emulsion Capacity (EC)

Adeyeye *et al*., [16], the procedure was used as 0.5g triplicate samples flour was added to 3 mL cm^3 of executive Chef vegetable oil in 10 mL cm^3graduated centrifuge tubes. The mixtures were stirred with a glass rod to disperse the flour in the oil. After holding for a period of 30 minutes, the volumes of separated oil were noted. The excess oil absorbed was expressed as the percentage oil bound by 100 g sample. The density of the oil was determined by means of specific gravity bottle.

$$\text{Calculation (\%)} = \frac{\text{(Initial Vol. of Oil – Final Vol. of Oil)}}{\text{(Wt of Sample X Density of Oil)}} \text{ X } 100$$

Determination of Elements

The methods adopted by Association of Oil Analytical Chemist (AOAC International) [13] were used in the determination of the mineral compositions.

STATISTICAL ANALYSIS

Data obtained were generated in triplicates and analyzed using Mean, Standard Deviation and one-way analysis of variance with Duncan Multiple Range test at 95% confidence.

RESULTS AND DISCUSSION

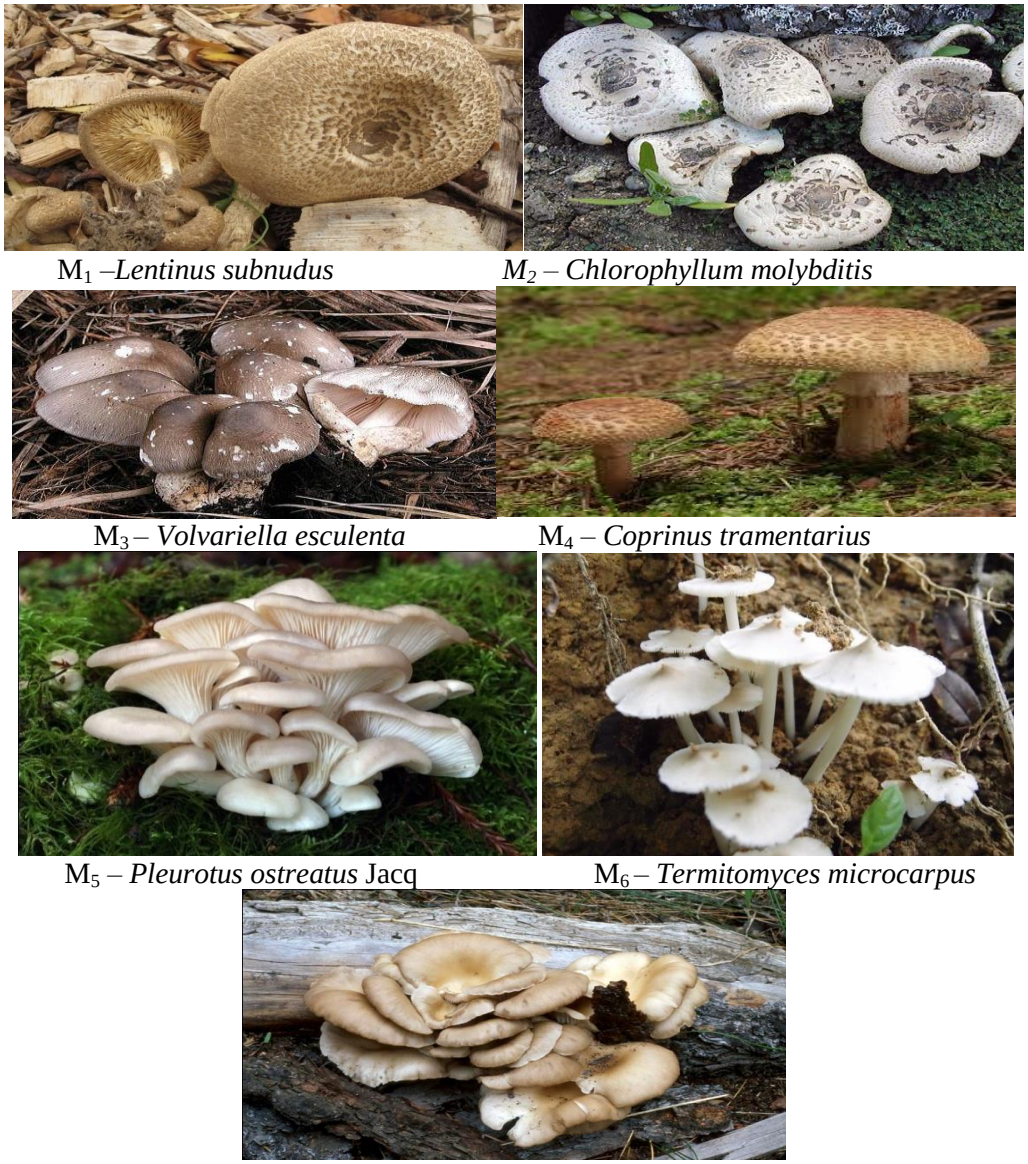
Table-2 showed the proximate contents of the samples in this work at $p<0.05$. The range of the contents was between 9.1 (M_2) - 33.07% (M_7), while fibre, fat, and NFE ranged respectively as follows: 4.15 (M_1) - 7.08% (M_4), 0.012 (M_2) - 0.89% (M_3), and 35.76 (M_3) - 63.52% (M_1). Adeyeye *et al.* [16], recorded between 36.6 and 43.1% in the mushroom sample researched upon. With these values, the protein contents in our samples were higher than theirs. The values were lower than 70.44 - 77.94% obtained by Pham *et al*., [17] for a defatted pumpkin seed meal. The differences in lipid contents in the samples were minor. Carbohydrate values of samples significantly differed ($p < 0.05$) and *Chlorophyllum molybdities* had the highest while *Volvariella esculenta* had the lowest. The fiber contents were low. According to Sudheep and Sridhar [18], fiber in diets nutritionally improves the digestibility by trapping fewer proteins and carbohydrates, the high fiber in the diet has several health benefits as it lowers the blood cholesterol and reduces the risks associated with the large bowel cancer. The high NFE content could probably be due to a higher level of non-fiber carbohydrates such as sugars [19]. The energy reported for cooked and uncooked *Agaricus abruptibulbus* by Sudheep and Sridhar [18] were 1433-1593 KJ/100 g and it was 266 KJ/100 g in *Volvariella speciosa* while 261 KJ/100 g was recorded by Nakalembe *et al*. [20] for Termitomyces *clypeatus*. Our energy results were between 850.97 KJ/100 g (M_3) and 1408.93 KJ/100 g (M_6). Significant differences ($p < 0.05$) were also observed between mushrooms. Proximate composition of the samples presented in Fig 2 showed that the energy, protein, fat, ash (mineral), and fiber contents showed wide variations among the mushroom species. From the chart, it was observed that sample M_6 was rich in protein (32.32%), ash (7.25%), and fiber (6.91%).

Table-3 showed the elements present in the mushroom samples. K was the highest out of the major elements, next is Na and Ca, while it was Mn for trace elements. The elements (K, P, Ca, and Mg) gave about 90% of the total mineral composition. Cd was not detectable and Pb was recorded in all the samples at low values. Significant differences ($p < 0.05\%$) in minerals determined were observed in all mushroom species. Cu, K, and P were in agreement with the Button and Portabello mushrooms [21]. In researches carried out in Budapest, Co was found to be 0.19–0.50 mg/kg [22] our results were above theirs. The maximum permissible limits released by SON [23] for Cd and Pb are 0.003 and 0.01 mgL respectively [24]. It is good to note, that consumers are not likely to be exposed to Cd, but care should be taken not to ingest Pb poison. The Pb presence could be due to the traffic flow of the area of harvest. Mushrooms provide low amounts of fat, this made them to be low-calorie foods [25]. The core constituents in the ash content of a mushroom sample are potassium and, depending on the mushroom, phosphorus or magnesium in addition to calcium, copper, iron, and zinc [26].

Tables 4-8 showed the effect of $NaSO_4$ on the EC and ES of the mushroom samples in percentage. The results in Table 4 showed the EC and ES of the mushroom samples in water. The results varied from 76.26±20.17 (M_2) to 85.70 ± 20.17% (M_7) and significantly differed from one another at $p > 0.05$. All samples showed the relatively good capacity of emulsion capacity. From the results, it was observed that the longer the length of time the lower the ES. The difference observed suggested an interaction existed between samples and water at a different time interval. The stable emulsion was due to the interfacial area which did not change with time.

The EC and ES of samples in different salt concentrations were shown in Tables-(5, 8). EC of the different flours ranged as follows: 64.48 - 86.18, 68.18 - 75.10, 67.18 - 74.51, and 61.48 -75.01% in 2, 4, 6, 8% of the salt concentrations respectively. Like water, the longer the length of time and higher salt concentrations, the lower the ES. In a comparison of salt concentrations and water for their effects on ES and EC, both cases showed the relative order of the oil used for the two solvents. Salt applications gave lowest ES and EC. These results indicated the interaction between the oil, salt solutions, the mushroom samples, and the blender used to form the emulsions.

The application of the salt showed a marked effect on the resulting EC and ES of the mushroom samples. In an experiment by Pearce and Kinsella [8], it was observed that the additions of salt and the use of blender resulted in reduced EC and ES compared with that obtained when water was added. In stable ES, the interfacial area did not change with time. Consequently, such emulsions have a constant turbidity. In this work, it was observed that coalescence and oiling-off caused an irreversible reduction in the interfacial area [8]. Creaming removed oil globules from the bulk of the emulsion but does not itself cause a reduction in the interfacial area of the whole emulsion. According to Kaushal *et al*. [27], the protein as the surface active agent stabilizes and forms the emulsion through the creation of electrostatic repulsion on the surface of oil droplet. Kaushal *et al*. [27], also quoted that ES can be greatly increased when highly cohesive films are formed by the absorption of rigid globular protein molecules that are more resistant to mechanical deformation.



M_1 –*Lentinus subnudus* *M_2 – Chlorophyllum molybditis*

M_3 – *Volvariella esculenta* M_4 – *Coprinus tramentarius*

M_5 – *Pleurotus ostreatus* Jacq M_6 – *Termitomyces microcarpus*

M_7 – Pleurotus pulmonarius

Figure 1-Pictures of the Mushroom Species used for this work

Table 1-Past Researches on functional properties' using different salts.

Reference	Country	Samples	Salts	Parameters Determined	Results Obtained
Idris et al., [28]	Sudan	Wheat bran proteins	NaCl	PS, EC, ES, FC, FS, LGC	Improved proteins properties
Ogungbemile et al., [12]	Nigeria	*Chenopodium quinoa*	NaCl, Na_2SO_4, KCl, K_2SO_4, CH_3COONa	LGC, EC, ES, WAC, FC, FS	Improved flour food property
Ahmed et al., [29]	Sudan	Legumes (White bean, Pigeon Pea, Cowpea, Hyacinth bean)	NaCl	EA, ES, FC, FS, PS	0.4-0.6M NaCl improved PS, FS, EA of samples, but, decreased ES and FC
Andualem and Gessesse [30]	Ethiopia	*Millettia ferruginea*	NaCl	EC, ES, FC, FS, WAC	Salt added up to a certain limit improved the sample Functionality
Pham et al., [19]	Vietnam	Pumpkin Seed	NaCl	WAC, OAC, EC, ES, FC, FS, GC	Salt addition improved the functional properties of pumpkin seed albumin, globulin, and glutamine

LGC – Least Gelation Capacity, EC - Emulsion Capacity, ES - Emulsion Stability, WAC - Water Absorption Capacity, FC - Foam Capacity, FS - Foam Stability, EA – Emulsifying Activity, PS - Protein Solubility, GC – Gelation Capacity, OAC – Oil Absorption Capacity.

Table 2-The Proximate Compositions of the Selected Species of Mushrooms (%).

Parameters	M_1	M_2	M_3	M_4	M_5	M_6	M_7
Crude Protein	16.06 ± 0.12^{b}	9.1 ± 0.15^{a}	12.36 ± 0.25^{ab}	13.80 ± 0.15^{a}	31.58 ± 0.23^{c}	32.32 ± 0.10^{c}	3.07 ± 0.89^{C}
Crude Fibre	4.15 ± 0.02^{a}	4.68 ± 0.16^{a}	5.35 ± 0.13^{ab}	7.08 ± 0.59^{b}	6.11 ± 0.32^{ab}	6.91 ± 0.11^{c}	4.19 ± 0.89^{a}
Crude Fat	0.71 ± 0.02^{c}	0.12 ± 0.02^{a}	0.89 ± 0.07^{a}	0.14 ± 0.12^{a}	0.72 ± 0.20^{c}	0.50 ± 0.21^{b}	0.8 ± 0.02^{a}
Ash	10.12 ± 0.2^{cd}	9.07 ± 0.02^{bc}	$8.11\pm.22^{ab}$	7.93 ± 0.02^{ab}	11.05 ± 0.20^{d}	7.25 ± 0.02^{a}	14.11 ± 2.01^{e}
NFE	63.52 ± 2.51^{bc}	71.22 ± 2.98^{bc}	35.76 ± 2.10^{b}	62.94 ± 2.52^{ab}	40.83 ± 2.10^{ab}	49.47 ± 2.10^{c}	42.37 ± 2.10^{ab}
Moisture	5.56 ± 0.32^{b}	5.81 ± 0.19^{b}	9.05 ± 0.13^{cd}	8.11 ± 2.17^{c}	9.71 ± 0.22^{d}	3.55 ± 0.28^{a}	5.46 ± 0.12^{b}
Dry Matter	92.78 ± 2.07^{bc}	92.11 ± 2.17^{bc}	91.11 ± 2.17^{abc}	89.12 ± 2.18^{ab}	88.11 ± 2.17^{a}	93.15 ± 2.23^{c}	90.11 ± 2.17^{abc}
Energy 1 (KJ/100 g)	379.13 ± 10.0^{b}	1369.88 ± 10.0^{b}	850.97 ± 8.5^{a}	1309.76 ± 10.0^{b}	1257.61 ± 9.5^{ab}	1408.93 ± 10.5^{c}	312.08 ± 10.0^{b}

All values were expressed as averages of triplicate determinations ± the standard deviations and values bearing the same superscripts in the same column are significantly not different ($p < 0.05$). NFE – Nitrogen Free Extract

Table 3-The Mineral Compositions of the Selected Species of Mushrooms.

Parameters	M_1	M_2	M_3	M_4	M_5	M_6	M_7
Ca	573 ± 2.30^{e}	326 ± 2.11^{b}	276 ± 2.41^{a}	460 ± 2.23^{c}	564 ± 2.11^{d}	668 ± 2.23^{f}	571 ± 2.45^{e}
K	1284 ± 2.32^{c}	926 ± 2.11^{a}	1179 ± 2.56^{b}	1298 ± 2.36^{c}	2516 ± 2.34^{d}	3680 ± 2.33^{f}	3014 ± 2.67^{e}
Na	575 ± 2.32^{c}	177 ± 2.56^{a}	585 ± 2.76^{c}	528 ± 2.43	556 ± 2.78^{c}	910 ± 2.56^{c}	860 ± 2.38^{d}
Mg	429 ± 2.34^{c}	169 ± 2.55^{b}	540 ± 2.67^{d}	111 ± 1.89^{ab}	396 ± 2.21^{c}	420 ± 2.89^{a}	460 ± 2.78^{c}
P	708 ± 2.02^{c}	480 ± 2.31^{a}	668 ± 0.02^{b}	716 ± 2.77^{d}	670 ± 2.09^{b}	884 ± 2.43^{f}	735 ± 2.56^{e}
Zn	2.15 ± 0.20^{c}	0.66 ± 0.02^{a}	1.37 ± 0.02^{b}	2.64 ± 0.02^{e}	1.33 ± 0.02^{b}	2.17 ± 0.02^{c}	2.35 ± 0.03^{d}
Mn	2.91 ± 0.07^{b}	3.23 ± 0.02^{d}	4.57 ± 0.02^{g}	4.22 ± 0.03^{f}	3.08 ± 0.02^{c}	3.76 ± 0.03^{c}	2.66 ± 0.02^{a}
Co	2.63 ± 0.02^{f}	1.67 ± 0.02^{d}	1.03 ± 0.02^{b}	0.54 ± 0.20^{a}	2.87 ± 0.02^{g}	1.34 ± 0.02^{c}	2.19 ± 0.02^{e}
Cu	0.75 ± 0.02^{d}	0.23 ± 0.23^{a}	0.57 ± 0.02^{c}	0.34 ± 0.03^{b}	1.14 ± 0.02^{f}	1.32 ± 0.02^{g}	0.85 ± 0.02^{e}

All values were expressed as averages of triplicate determinations ± the standard deviations and values bearing the same superscripts in the same column are significantly not different ($p < 0.05$).

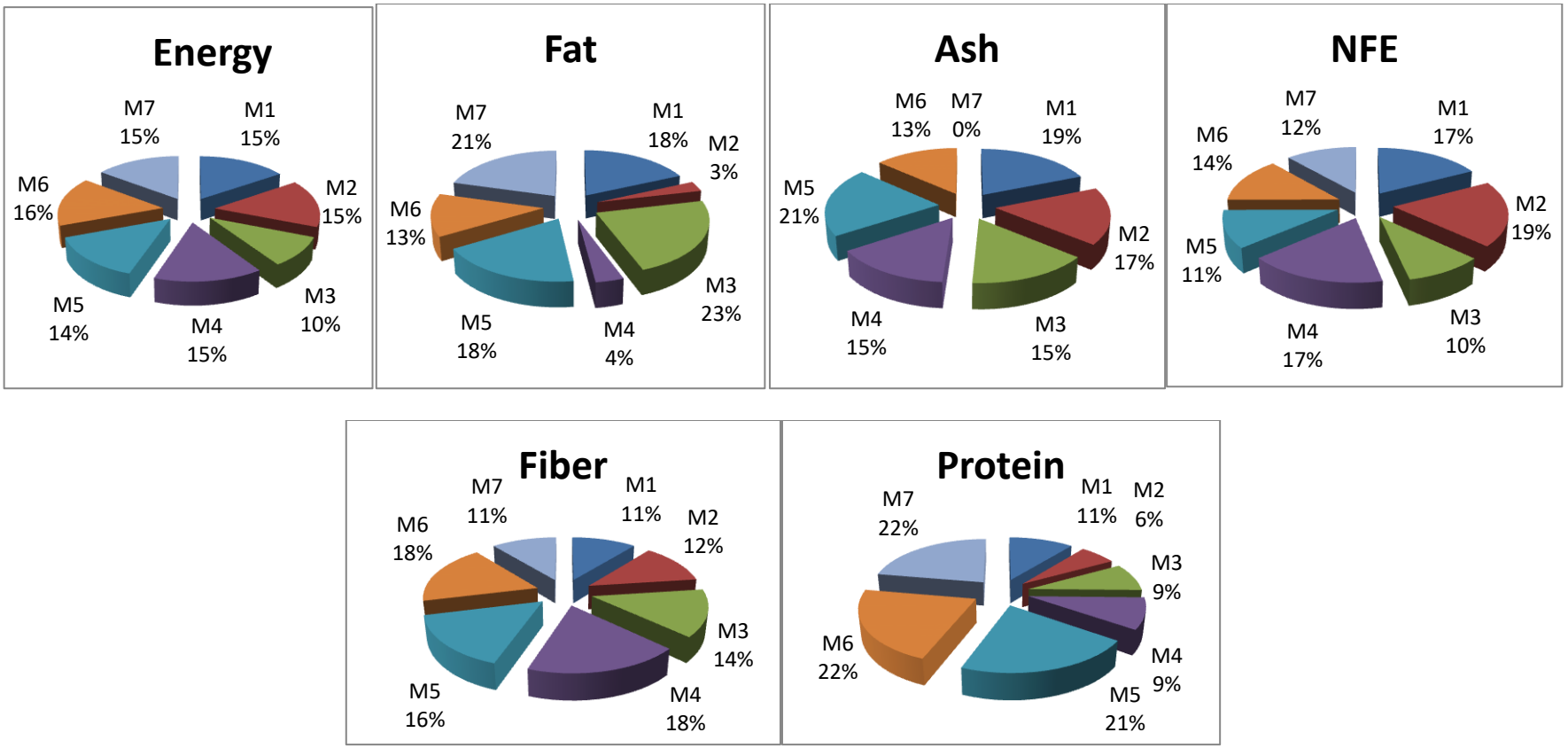


Figure 2-Pie Chart of the Proximate Composition of the Mushroom Species used for this work

Lentinus subnudus Berk (M_1), *Chlorophyllum molybditis* (M_2), *Volvariella esculenta* (M_3), *Coprinus tramentarius* (M_4), *Pleurotus ostreatus* Jacq (M_5), *Termitomyces microcarpus* (M_6) and *Pleurotus pulmonarius* (M_7).

Table 4-Emulsion Capacity and Stability of Selected Varieties of Mushrooms in Water (%).

Time (h)	Samples						
	M_1	M_2	M_3	M_4	M_5	M_6	M_7
Capacity 0	78.29±21.26^a	76.26±20.17^b	78.48±19.00^c	78.40±19.17^a	80.49±19.17^b	87.26±20.17^b	85.70±20.17^c
1	38.22±17.51^a	37.37±20.03^a	34.86±20.03^b	40.37±20.02^a	42.11±20.03^a	45.20±20.03^a	40.33±20.03^b
2	38.14±18.72^a	37.55±20.17^a	38.29±20.17^b	40.29±21.17^a	36.55±20.17^a	41.45±20.17^a	39.49±20.17^b
3	34.43±19.18^a	37.44±19.82^a	38.29±19.82^b	40.07±20.82^a	34.22±18.82^a	41.44±19.82^a	38.52±18.82^{ab}
4	34.34±20.90^a	35.44±19.99^a	38.18±19.42^b	40.34±20.99^a	34.41±19.99^a	40.94±19.99^a	38.30±20.99^{ab}
5	33.29±20.57^a	35.56±20.05^a	38.18±18.90^b	40.51±20.05^a	34.26±20.05^a	39.56±20.05^a	38.26±20.05^{ab}
6	32.37±19.40^a	35.58±21.45^a	38.11±21.45^a	40.41±19.45^a	34.37±21.45^a	39.55±21.45^a	37.41±21.45^a
22	32.27±19.19^a	35.59±21.18^a	38.10±21.18^b	40.59±21.18^a	34.58±21.18^a	39.15±21.18^a	37.36±21.18^a
24	32.37±20.55^a	35.33±20.00^a	38.00±20.00^b	38.33±19.95^a	34.46±19.00^a	39.33±20.00^a	37.30±19.56^a

All values were expressed as averages of triplicate determinations ± the standard deviations and values bearing the same superscripts in the same column are significantly not different ($p < 0.05$).

Table 5-Emulsion Capacity and Stability of Selected Varieties of Mushrooms in Sodium Sulphate (2%).

Time (h)	Samples						
	M_1	M_2	M_3	M_4	M_5	M_6	M_7
Capacity 0	68.11±1.26^b	72.11±2.17^c	64.48±1.00^c	78.40±1.2.0^b	75.15±2.17^b	85.15±2.17^b	86.18±2.1^b
1	32.13±2.51^a	38.37±2.03^b	24.86±2.03^b	46.37±1.02^a	43.11±2.03^a	55.20±2.03^a	56.49±2.0^a
2	32.11±2.72^a	38.55±2.17^b	24.29±2.17^b	46.29±1.17^a	43.55±2.17^a	55.45±2.17^a	56.19±2.1^a
3	32.77±2.18^a	38.44±1.82^{ab}	24.45±1.82^b	46.07±2.82^a	43.22±1.82^a	53.44±1.82^a	54.12±1.8^a
4	32.65±2.90^a	38.44±1.99^{ab}	24.57±1.42^b	46.34±2.99^a	43.41±1.99^a	49.94±1.99^a	54.11±2.9^a
5	32.29±2.57^a	38.15±2.05^a	24.52±1.90^b	44.51±2.00^a	41.26±2.05^a	49.56±2.05^a	50.11±2.0^a
6	30.15±2.40^a	37.10±2.45^a	24.58±2.45^b	44.41±1.45^a	41.37±2.45^a	49.55±2.45^a	50.00±2.4^a
22	20.16±2.19^a	36.09±2.18^a	24.10±2.18^a	44.40±2.18^a	41.58±2.18^a	47.15±2.18^a	48.24±2.1^a
24	20.15±2.18^a	36.33±2.00^b	24.47±2.00^a	44.48±1.95^a	41.46±1.98^a	47.33±2.00^a	48.06±2.0^a

All values were expressed as averages of triplicate determinations ± the standard deviations and values bearing the same superscripts in the same row are significantly not different ($p < 0.05$).

Table 6-Emulsion Capacity and Stability of Selected Varieties of Mushrooms in Sodium Sulphate (4%).

Time (h)	Samples						
	M_1	M_2	M_3	M_4	M_5	M_6	M_7
Capacity 0	70.11±1.26^{b}	75.11±2.17^{c}	72.48±1.00^{b}	70.40±1.2.0^{c}	71.15±2.17^{b}	75.15±2.17^{b}	68.18±2.1^{b}
1	40.13±2.51^{a}	40.37±2.03^{b}	23.86±2.03^{a}	35.37±1.02^{b}	40.11±2.03^{a}	43.20±2.03^{a}	36.49±2.0^{a}
2	40.11±2.72^{a}	40.55±2.17^{b}	23.29±2.17^{a}	35.29±1.17^{b}	40.55±2.17^{a}	43.45±2.17^{a}	36.19±2.1^{a}
3	38.77±2.18^{a}	40.44±1.82^{b}	23.45±1.82^{a}	35.07±2.82^{ab}	40.22±1.82^{a}	43.44±1.82^{a}	36.12±1.8^{a}
4	38.65±2.90^{a}	38.44±1.99^{ab}	23.57±1.42^{a}	35.34±2.99^{ab}	38.41±1.99^{a}	43.94±1.99^{a}	34.11±2.9^{a}
5	38.29±2.57^{a}	38.15±2.05^{ab}	23.52±1.90^{a}	35.51±2.00^{ab}	38.26±2.05^{a}	41.56±2.05^{a}	34.11±2.0^{a}
6	38.15±2.40^{a}	38.10±2.45^{b}	23.58±2.45^{a}	33.41±1.45^{ab}	38.37±2.45^{a}	41.55±2.45^{a}	34.00±2.4^{a}
22	38.16±2.19^{a}	36.09±2.18^{a}	23.10±2.18^{a}	33.40±2.18^{a}	38.58±2.18^{a}	41.15±2.18^{a}	34.24±2.1^{a}
24	38.15±2.18^{a}	30.33±2.00^{a}	23.47±2.00^{a}	33.48±1.95^{a}	38.46±1.98^{a}	41.33±2.00^{a}	34.06±2.0^{a}

All values were expressed as averages of triplicate determinations ± the standard deviations and values bearing the same superscripts in the same row are significantly not different ($p < 0.05$).

Table 7-Emulsion Capacity and Stability of Selected Varieties of Mushrooms in Sodium Sulphate (6%).

Time (h)	Samples						
	M_1	M_2	M_3	M_4	M_5	M_6	M_7
Capacity 0	70.00±1.2^{b}	74.51±2.17^{c}	72.00±1.0^{b}	69.30±1.2.0^{c}	70.15±2.1^{b}	71.45±2.0^{b}	67.18±2.7^{b}
1	39.13±2.5^{a}	40.77±2.03^{b}	22.86±2.03^{a}	34.37±1.02^{b}	39.10±2.03^{a}	41.10±2.03^{a}	34.32±2.0^{a}
2	39.11±2.72^{a}	40.65±2.17^{b}	22.29±2.17^{a}	34.19±1.17^{b}	39.05±2.17^{a}	41.05±2.17^{a}	34.32±2.1^{a}
3	36.77±2.18^{a}	40.54±1.82^{ab}	22.45±1.82^{a}	34.17±2.82^{ab}	39.00±1.82^{a}	41.04±1.82^{a}	34.12±1.8^{a}
4	36.65±2.90^{a}	38.54±1.99^{ab}	22.57±1.42^{a}	34.14±2.99^{ab}	38.42±1.99^{a}	40.50±1.99^{a}	33.11±2.9^{a}
5	36.29±2.57^{a}	38.15±2.05^{a}	22.52±1.90^{a}	34.11±2.00^{ab}	38.24±2.05^{a}	40.56±2.05^{a}	33.11±2.0^{a}
6	36.15±2.40^{a}	38.10±2.45^{a}	21.58±2.45^{a}	33.41±1.45^{ab}	38.20±2.45^{a}	39.55±2.45^{a}	33.04±2.4^{a}
22	36.16±2.19^{a}	36.09±2.18^{a}	21.10±2.18^{a}	33.40±2.18^{a}	38.18±2.18^{a}	39.15±2.18^{a}	33.00±2.1^{a}
24	36.15±2.18^{a}	31.33±2.00^{b}	21.47±2.00^{a}	33.48±1.95^{a}	38.18±1.98^{a}	39.00±2.00^{a}	33.00±2.0^{a}

All values were expressed as averages of triplicate determinations ± the standard deviations and values bearing the same superscripts in the same row are significantly not different ($p < 0.05$).

Table 8-Emulsion Capacity and Stability of Selected Varieties of Mushrooms in Sodium Sulphate (8%).

Time (h)	Samples						
	M_1	M_2	M_3	M_4	M_5	M_6	M7
Capacity 0	70.11±1.26^{ab}	75.00±2.00^{a}	61.48±1.00^{c}	73.40±1.2.0^{c}	75.05±2.17^{b}	77.05±2.17^{b}	65.00±2.17^{c}
1	44.13±2.51^{ab}	46.37±2.03^{a}	25.86±2.03^{a}	46.37±1.02^{b}	38.11±2.03^{a}	41.20±2.03^{a}	30.49±2.03^{b}
2	44.11±2.72^{ab}	46.55±2.17^{a}	25.29±2.17^{a}	44.29±1.17^{ab}	38.55±2.17^{a}	41.45±2.17^{a}	30.19±2.17^{b}
3	42.77±2.18^{b}	46.44±1.82^{a}	25.45±1.82^{a}	44.07±2.82^{ab}	38.22±1.82^{a}	41.44±1.82^{a}	30.12±1.82^{a}
4	42.65±2.90^{ab}	44.44±1.99^{a}	25.57±1.42^{a}	44.34±2.99^{ab}	38.41±1.99^{a}	41.94±1.99^{a}	28.21±2.99^{a}
5	40.29±2.57^{a}	44.15±2.05^{a}	25.52±1.90^{a}	42.51±2.00^{a}	36.26±2.05^{a}	38.56±2.05^{a}	28.21±2.05^{a}
6	40.15±2.40^{a}	44.10±2.45^{a}	25.58±2.45^{a}	42.41±1.45^{a}	36.37±2.45^{a}	38.55±2.45^{a}	28.40±2.45^{a}
22	40.16±2.19^{a}	44.09±2.18^{a}	25.10±2.18^{a}	42.40±2.18^{a}	36.58±2.18^{a}	38.35±2.18^{a}	28.00±2.18^{a}
24	40.15±2.18^{a}	44.33±2.00^{a}	24.47±2.00^{a}	42.48±1.95^{a}	36.46±1.98^{a}	38.24±2.00^{a}	28.00±2.09^{a}

All values were expressed as averages of triplicate determinations ± the standard deviations and values bearing the same superscripts in the same row are significantly not different ($p < 0.05$).

Conclusion

This work revealed that the selected mushrooms from the southwestern part of Nigeria were good sources of protein. The major and trace metals were present in adequate concentrations. It is gratifying to note that the Cd and Pb values were normal. In the study, EC and ES were affected by different salt concentrations. The good emulsifying capacity and stability showed the usefulness of the samples in the food industries and food formulations.

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